Note

Metal Distribution in the Laguna Lake Water System and Adsorption of Some Metals by Carbonized Wood Powder*[1]*[2]

Lilibeth L. PULIDO*[3], Belen B. BISANA*[4], Toshimitsu HATA*[3], Yuji IMAMURA*[3], Shigehisa ISHIHARA*[3] and Takeshi KAJIMOTO*[5]

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Abstract——The metal distribution in the Laguna lake water system was assessed using water samples taken from the surface, middle and bottom portions of the lake at five designated sampling points. Trial purification of the wastewater was conducted using raw and carbonized wood powder from wood wastes of *Acacia mangium*. Beneficial and dangerously toxic metals were present in all the water samples. Sodium (Na) was the most dominant alkali metal followed by potassium (K), magnesium (Mg) and calcium (Ca). Toxic metals such as arsenic (As), cadmium (Cd), cobalt (Co), chromium (Cr), copper (Cu), lead (Pb), iron (Fe), mercury (Hg), zinc (Zn), etc., were found but each concentration was below the water quality criteria set by the National Pollution Control Commission of the Philippines. Adsorption tests showed that wood waste from *Acacia mangium* could be a potential purification material in treating Laguna lake water samples, and especially raw and carbonized wood powder of this species could be used as material in adsorbing heavy metals like Zn and Cu.

Keywords : metal, Laguna lake, *Acacia mangium*, carbonization temperature, zinc (Zn), copper (Cu)

1. Introduction

The Philippines, known for rich natural resources, has been endowed with a large and highly productive body of freshwater whose strategic location, physical attributes and economic and ecological significance make it vitally important. Laguna lake, Asia's largest and most utilized lake has a total land area of 90,000 hectares and is situated in one of the most densely populated and scenic spots in the country[1]. It is surrounded by many factories and densely populated towns and cities, making this lake a very important water resource in Metro Manila and nearby towns. The lake has three separate bays, the West bay, Central bay, and East bay that converge towards the south resembling a large bird foot which they call a South bay (Fig. 1).

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*[2] This work was funded by the Japan Society for the Promotion of Science.
*[3] Laboratory of Wood Composite.
*[4] Forest Products Research and Development Institute, Philippines.
*[5] Wakayama Industrial Technology Center, Wakayama City.

Laguna lake is a multi-purpose resource. At present, it is used extensively for aquaculture by means of fish-pens and fish-cages. Lakewater is also used for domestic and industrial wastes disposal, irrigation and some industries depend on the lake for cooling water, power generation and for transportation of fuel, raw materials, and finished products. The conversion of the lake into multi-purpose resource had increased food production, fish production, generated more power and created employment in the basin. However, the same processes caused negative effects in the environment[2]. The continuous deterioration of the water quality limits its resource applications.

One of the most important physico-chemical parameters in assessing water quality is the presence of metals. The concentration of metal in the waters and sediments of the lake, and some tributaries show signs of industrial pollution. Based on recent records of the Laguna Lake Development Authority, there are 1,075 industrial establishments in the basin, most of which are concentrated on the western slope of the lake. Only 51% of all industries have wastewater treatment facilities. The recent Feasibility Study on Laguna Lake Toxic and Hazardous Waste Management revealed that most of the industrial establishments contribute significantly to the pollution loading of the lake. Furthermore, 41% of the industries discharge an increasing number of toxic and hazardous substances which exceed the chronic criteria for the protection of aquatic life[2].

Under this condition, accurate and precise analyses of metals present in the lake have become essential. In this study, we attempted to assess the distribution and levels of metals and other elements in the water system and identify possible probable sources and reasons of the high concentrations where encountered. Trial purification of wastewater was conducted using raw and carbonized wood from wastes of *Acacia mangium*, plantation species abundantly found in the Philippines.

2. Materials and Methods

2.1 Water analysis of Laguna lake

Waste water of Laguna lake was taken from five sampling areas, shown in Fig. 1, namely: Taytay, Taguig, Jalajala, Baras and Binangonan. Samples were taken from the surface, middle ($\approx$10.4-m depth) and bottom ($\approx$20.8-m depth) portions of the lake, using three replicates. The concentrations of metals and other elements in the sample were qualitatively measured using inductively coupled machine (ICP).

2.2 Carbonization of wood sample

The air-dried *Acacia mangium* veneer core was ground into powder form and dried overnight in an oven at 105°C. One hundred grams (100 g) of powdered material was carbonized separately for one hour at 200, 400, 600 and 800°C using a rotary carbonizer. Nitrogen gas was purged at 100 ml/min. The carbonizer was left to cool for overnight

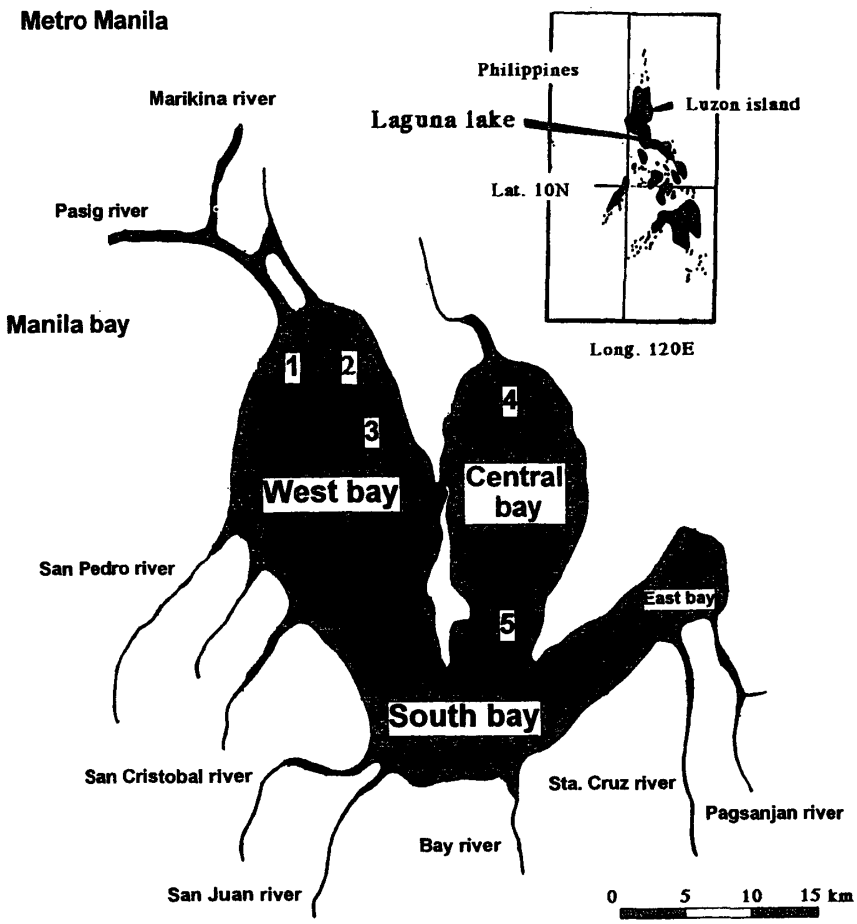

Fig. 1. Sampling stations in the Laguna lake basin.
1: Taguig, 2: Taytay, 3: Binangonan, 4: Baras, 5: Jalajala.

before it was taken out of the furnace.

2.3 Purification treatment

Five hundred milligrams (500 mg) of raw and carbonized wood was used for every 50 ml of water sample. Mercury (Hg), cadmium (Cd), copper (Cu) and zinc (Zn) were quantitatively analyzed using atomic absorption spectrometer (AAS).

3. Results and Discussion

3.1 Qualitative and quantitative analyses of heavy metals and other elements in lake water

The effects of metals in water and waste water range from beneficial through dangerously toxic. Some metals may be either beneficial or toxic depending on their concentrations. Table 1 shows the qualitative analysis of metals and other elements in the Laguna lake water samples. The abundance of alkali and alkaline earth metals in the earth's crust range from the most abundant metals like calcium, sodium, magnesium and

Table 1. Qualitative analysis of metals and other elements in the Laguna lake water samples.

Classification	Metal/Element	Sampling station				
		Taguig (1)	Taytay (2)	Binangonan (3)	Baras (4)	Jalajala (5)
s-block metal						
1. Alkali metal (Group 1)	Potassium (K)	□	□	□	□	□
	Sodium (Na)	○	○	○	○	○
2. Alkaline earth metal (Group 2)	Barium (Ba)	+	+	+	+	+
	Calcium (Ca)	□	□	□	□	□
	Magnesium (Mg)	□	□	□	□	□
d-block metal (Groups 4–11)	Chromium (Cr)	+	+	+	+	+
	Cobalt (Co)	+	+	+	+	+
	Copper (Cu)	+	+	+	+	+
	Iron (Fe)	+	+	+	+	+
	Manganese (Mn)	+	+	+	+	+
	Molybdenum (Mo)	+	+	+	+	+
	Nickel (Ni)	+	+	+	+	+
	Titanium (Ti)	+	+	+	+	+
	Vanadium (V)	+	+	+	+	+
	Palladium	+	+	+	+	+
	Copper (Cu)	+	+	+	+	+
	Silver (Ag)	△	△	△	△	△
p-block metal (Group 13/111)	Aluminum (Al)	+	+	+	+	+
	Lead (Pb)	+	+	+	+	+
	Tin (Sn)	+	+	+	+	+
Group 12 metal	Cadmium (Cd)	+	+	+	+	+
	Mercury (Hg)	+	+	+	+	+
	Zinc (Zn)	+	+	+	+	+
Nitrogen group (Group 15/V)	Antimony (Sb)	+	+	+	+	+
	Arsenic (As)	+	+	+	+	+
	Phosphorous (P)	+	+	+	+	+
Oxygen group (Group 16/V1)	Selenium (Se)	+	+	+	+	+
	Sulfur (S)	□	□	□	□	□
Halogen group (Group 17/V11)	Bromine (Br)	□	□	□	□	□
Boron Group (Group 13/111)	Boron (B)	△	△	△	△	△
Carbon group (Group 14/IV)	Silicon (Si)	△	△	△	△	△

Notes: + : less than 1 ppm ; △ : more than 1 ppm ; □ : more than 10 ppm ; and ○ : more than 100 ppm. Classification of elements was referred to "Inorganic Chemistry" by D.F. Shriver, P.W. Atkins and Ch.H. Langford. ed. : D.F. Shriver, P.W. Atkins and Ch. H. Langford. Oxford University Press, Oxford (1994).

potassium to the relatively rare metals, cesium to beryllium[3]. In Table 1, the concentration of alkali and alkaline earth metals was relatively high compared to the other types of metals. Sodium (Na) was found to be more than 100 ppm followed by potassium (K), magnesium (Mg) and calcium (Ca) which were more than 10 ppm. These metals are abundantly found in sea water and brines and considered to be vital to many metabolic processes as especially noted in calcium and magnesium[3,4].

Bromine (Br) and sulfur (S) were found to be within the concentration of more than 10 ppm. Regarding these elements, sulfur is also a very important component of the ecosystem and is considered as a major nutrient by all organisms[5], and bromine, on the other hand, is abundantly found in sea water just like the alkali metals[6]. The rest of the metals except for silver (Ag) and two of the non-metallic elements, boron and silicon, was found to be less than 1 ppm in concentration.

Analyses of data showed that the metals which the Philippine government considered to be toxic if the concentrations were above the permissible levels such as for arsenic (As), cadmium (Cd), cobalt (Co), chromium (Cr), copper (Cu), lead (Pb), iron (Fe), mercury (Hg), zinc (Zn), etc. were found in all the water samples.

Some of the metals were quantitatively analyzed on Cd, Cu, Hg and Zn. These metals were selected since they are the priority pollutants commonly discharged in the lake. Also, these are fairly common metal impurities in many water systems because they make up the earth's crust which are mostly found in industrial areas[7]. Since the lake is surrounded by industrial plants and bedrock sources in the case of mercury, the above metals was assumed to be of high concentration. However, the concentration of Cd and Hg were not detected

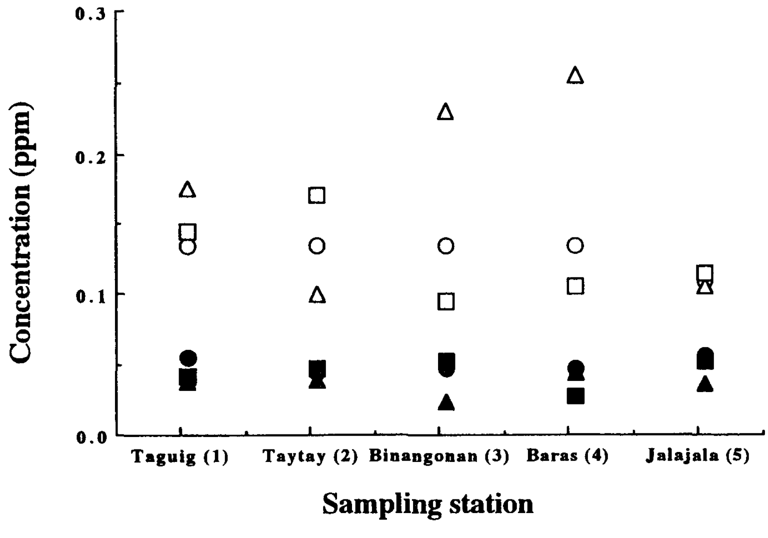

Fig. 2. Concentration of zinc (Zn) before and after soaking raw wood powder of *Acacia mangium*.
Legend : before soaking, ○ : surface, △ : middle, □ : bottom.
after soaking, ● : surface, ▲ : middle, ■ : bottom.

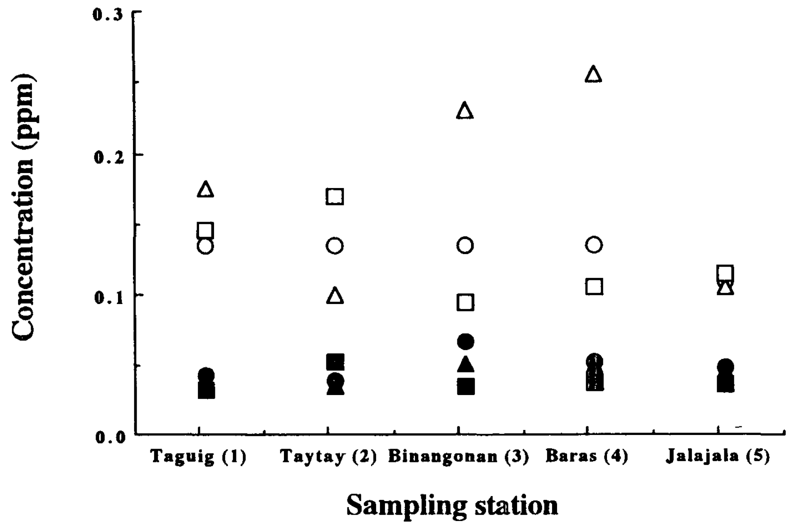

Fig. 3. Concentration of zinc (Zn) before and after soaking wood powder of *Acacia mangium* carbonized at 800°C.
Legend: Same as in Fig. 2.

because no peak appeared during the analysis. In Fig. 2, very little difference can be observed on the actual concentration of Zn present in the water samples in all the sampling stations. Disposal of Zn in the area is very frequent and that the lake is a closed system so there was a possibility that the concentration will be the same in almost all the bays, thus in all sampling stations. The concentration of Cu was the same in all the sampling stations as shown In Fig. 3. The concentration of the above metals fell below water quality criteria set by the National Pollution Control Commission of the Philippines.

3.2 Effects of raw and carbonized wood on the removal of heavy metals

After soaking raw and carbonized wood in the water samples, almost all the Zn ions were adsorbed as reflected in the concentration of the water samples, as shown in Figs. 2 and 3. Except for the wood powder carbonized at 200°C, regardless of whether the wood has been carbonized or not, Zn was easily adsorbed by the wood materials. In our previous experiment, the same trend was found in the adsorption of Zn in aqueous solution using sugi (*Cryptomeria japonica* D. Don) wood powder as adsorbent material[8]. This finding was attributed mainly to the ionization potential of this metal. Further, the concentration of the water samples might be very low, thus all the Zn ions were adsorbed by the wood materials.

The same trend was observed in the adsorption of Cu, as reflected in Figs. 4 and 5. Eventhough almost all of the Cu was adsorbed to raw wood powder and carbonized wood powder, it can be observed that the amount of Cu adsorbed by wood powder carbonized at 800°C was greater compared to raw wood powder and even to the other carbonized wood powder. The reason for this cannot be further explained based from this experiment.

The lignin component of the wood which is known to be useful for water purposes,

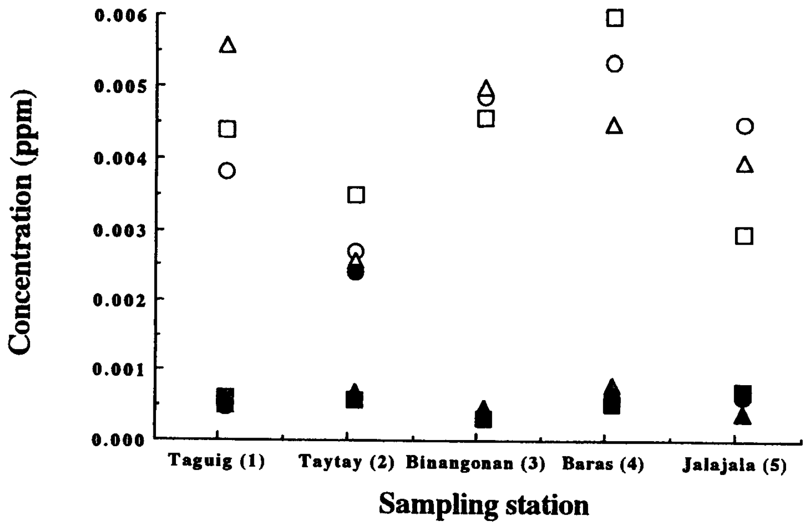

Fig. 4. Concentration of copper (Cu) before and after soaking raw wood powder of *Acacia mangium*.
Legend: Same as in Fig. 2.

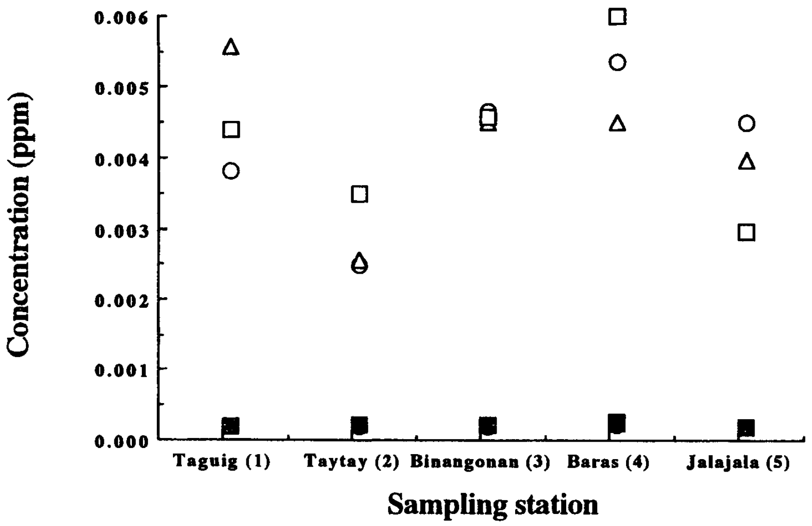

Fig. 5. Concentration of copper (Cu) before and after soaking wood powder of *Acacia mangium* carbonized at 800°C.
Legend: Same as in Fig. 2.

especially for the removal of metal deposits and purification[9] can be a possible reason in the good performance of the raw wood powder and low temperature carbonized wood powder. On the other hand, the electric conductivity property, which was improved after the wood evolved combustible and incombustible gases during carbonization at high temperature, might have enhanced the adsorption of the above metals.

4. Conclusions

Beneficial and dangerously toxic metals were present in all the water samples. Sodium

(Na) was the most dominant alkali metal followed by potassium (K), magnesium (Mg) and calcium (Ca). Bromine (Br) and sulfur (S) were also found to be abundant in the area. The dangerously toxic metals such as arsenic (As), cadmium (Cd), cobalt (Co), chromium (Cr), copper (Cu), lead (Pb), iron (Fe), mercury (Hg), zinc (Zn), etc., were of concentrations below the water quality criteria set by the National Pollution Control Commission of the Philippines.

Wood waste from *Acacia mangium* can be a potential adsorbent material in purifying Laguna lake water samples. Raw and carbonized wood powder of this species can be used as material in adsorbing heavy metals like Zn and Cu.

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